

## SOIL ANIMALS AND NITROGEN MIGRATION IN AN ECOSYSTEM

S. A. GORDIENKO,  
A. D. POKARŽEVSKIJ, D. P. KRIVOLUTZKIJ, A. N. SEVERTZOV\*

Institute of Landscape Ecology Czechoslovak Academy Science, České Budějovice, Czechoslovakia

\* Institute of Evolutionary Animal Morphology and Ecology of the USSR Academy Science, Moscow, USSR

### Abstract

Gordienko S. A., Pokarževskij A. D., Krivolutzkij D. P., Severtzov A. N.: Soil animals and nitrogen migration in an ecosystem. *Ecology (CSSR)*, Vol. 3, No. 4, 391—397, 1984.

Nitrogen migration and role animals in this process was studied in the Aljehkin-Central-Chernosem Biosphere Reserve in Kursk, where soil fauna research has been carried out for a long time. Nitrogen is the most important component of living organisms and its compounds (proteins, nucleic acids, aminoacids) and play the paramount role in functioning of living matter. Soil animals appeared to have great influence on nitrogen migration in an ecosystem. Nitrogen contents in most animal species in some what less than 10% of dry mass. Practically all animals concerned and are concentrators of nitrogen. Having defined the pool of the most important chemical elements at least of animals authors find out that microorganisms are the main component of the soil subecosystem, influencing the productivity of chemical populations, animal community structure in soil and hence the structure of the whole ecosystem.

### Introduction

The study of soil animal significance in nutrient cycling in ecosystems started with the research of their role in nitrogen migration (Satchell, 1963). It is not surprising, since nitrogen is the most important component of living organisms and its compounds (proteins, nucleic acids, aminoacids) play the paramount role in functioning of living matter. The value of nitrogen migration through earthworm population was compared with value of nitrogen fixation, soil animals appeared to have great influence on nitrogen migration in an ecosystem.

Then, however, the interest in studying the participation of soil animals in nitrogen turnover has been decreased, because of development of radioecological research and studies of soil animal significance in migration of other elements and pollutants (lead, cadmium etc.). In spite of that, from time to time, works dedicated to a certain extent to soil animal influence on nitrogen turnover have appeared. On the whole, we know far less about an animal role in nitrogen migration than about that in other element migration for example, calcium or magnesium.

We have shown in recent works (Pokarzhevskij, Krivolutzkij, 1981; Pokarzhevskij, Gordienko, 1983), that nitrogen combinations, firstly, proteins, with potassium and phosphorus can be factors limiting the productivity of animal populations and animal communities structure. On the other hand, there is a set of other organic nitrogen compounds which have the great significance in functioning of living matter. Estimation of animal role in total nitrogen turnover must be therefore the base for determination of significance of different nitrogen compounds in forming the structure and functioning of animal communities.

## Materials and methods

With this aim our material (soil animals, plants, litter, soil) for the determination of nitrogen content and the estimation of value of nitrogen migration through soil animal population has been gathered in the Aljekhin-Central-Chernosem Biosphere Reserve in Kursk where soil fauna research has been carried out for a long time. (Descriptions of plots and field methods are given in Krivolutzkij, Pokarzhevskij, 1977.)

Nitrogen was determined by Chmeleva's and Tjuterev's methods (Pleshkov, 1977), which is a modification of Kjeldahl's method. Samples of dry animal tissues (10 mg), dry plant tissues (100–150 mg) and soil (500 mg), were digested by sulphuric acid periodically adding some drops of 30% peroxid in thermic tubes. After decoloration the tube content was qualitatively transferred in 100 ml measuring flask. For nitrogen determination aliquote (0.5–2 ml) was taken in 100 ml measuring flask, neutralized by 10% NaOH, adding 3–5 ml of segnetic salt. Then in the flask 60 ml of distilled water was added, mixture and 2 ml of Nessler's solution added. Flask content was filled up to the sign with distilled water and after 5 min the nitrogen concentrations were determined colorimetrically at  $\lambda = 410$  nm (limits of concentrations 0.02–0.15 mg in 100 ml of solutions). Solutions must be absolutely transparent. Nitrogen content is expressed in % of dm.

## Results and discussion

Nitrogen concentrations in soil animals vary in relatively wide ranges (Table 1) and depend apparently, on relationships between nitrogen compounds bound in organic matter and nitrogen salts accumulated in the excretory system. It is likely that salt (urates) accumulation is determined by the differences in nitrogen content between individuals of the species concerned. In fact, nitrogen content in most animal species is somewhat less than 10% of dry mass, which is in correspondence with the known data (Satchell, 1963; McBrayer, 1977; Perkins, 1978). It is of interest that the presence of shells influences nitrogen content value in bodies of *Bradybaena fruticum*, while the concentration value in Diplopoda and Isopoda with calcinated integuments is nearly 10%. If these data are calculated for ash-free weight, the value of concentration will range between 13–15%, i.e. equal to that of insects. This fact has the same explanation as for insects, i.e. the accumulation of nitrogen salts in excretory system. In favour of this assumption speaks the relatively low protein content in diplopods, isopods and insects if compared with earthworms or chilopods (Pokarzhevskij, Krivolutzkij, 1981).

Practically all animals concerned are concentrators of nitrogen. Its content in their bodies is 2–5 times higher than in their food (Table 2); animals can thus have a deficit of this element, as it has been shown for other elements: phosphorus and potassium (Pokarzhevskij, Krivolutzkij, 1981; Pokarzhevskij, Gordienko, 1984).

The nitrogen distribution in particular ecosystem compartments is in some extent similar to the distribution of other limiting elements (Table 3). It is obvious that soil

Table 1. Nitrogen content in different species of soil animals in percents of dry weight (in brackets number of samples)

Species	N [%]	Species	N [%]
<i>Enchytraeidae</i>	5.3 (1)	<i>Carabus stscheglovi</i>	11.2 (1)
<i>Lumbricus terrestris</i>	10.3 ± 1.2 (5)	<i>Carabus violaceus</i>	11.7 ± 1.4 (3)
<i>Lumbricus rubellus</i>	8.5 ± 1.2 (2)	<i>Calosoma sycophanta</i>	10.4 ± 0.1 (2)
<i>Dendrobacna octaedra</i>	11.3 ± 2.9 (3)	<i>Pterostichus melanarius</i>	11.1 ± 2.2 (4)
<i>Dendrodrilus rubidus</i>	8.0 (1)	<i>Pterostichus oblongopunctatus</i>	7.4 ± 1.9 (3)
<i>Eisenia nordenskioldi</i>	11.6 ± 0.8 (4)	<i>Agonum assimile</i>	9.1 ± 2.7 (3)
<i>Nicodrilus caliginosus</i>	9.1 ± 1.0 (5)	<i>Zabrus tenebroides</i>	8.8 ± 0.6 (2)
<i>Nicodrilus roseus</i>	11.1 ± 0.9 (3)	<i>Staphylinus erythropterus</i>	10.4 ± 0.1 (3)
<i>Octolasion lacteum</i>	16.0 ± 0.4 (2)	<i>Stenus sp.</i>	12.7 ± 2.8 (2)
<i>Bradybaena fruticum</i>	2.7 ± 0.1 (2)	<i>Philonthus decorus</i>	15.2 ± 1.4 (3)
<i>Deroceras reticulatus</i>	6.9 ± 1.2 (2)	<i>Dorcardion equestre</i>	8.6 ± 1.3 (3)
<i>Trachelipus rathkei</i>	10.8 ± 2.0 (4)	<i>Silpha carinata</i>	20.1 ± 0.6 (3)
<i>Chromatoiulus kievensis</i>	9.3 ± 1.3 (5)	<i>Prosternon tessellatum</i>	8.8 ± 0.0 (2)
<i>Chromatoiulus rossicus</i>	6.6 ± 0.3 (4)	<i>Selatosomus aeneus larv.</i>	14.7 ± 1.5 (3)
<i>Sarmatiulus kessleri</i>	10.8 ± 1.7 (6)	<i>Agriotes sputator larv.</i>	18.3 (1)
<i>Turanodesmus dmitrievi</i>	7.1 (1)	<i>Lacon murinus</i>	8.4 ± 0.3 (2)
<i>Geophilidae</i>	13.4 ± 0.7 (2)	<i>Geotrupes stercorosus</i>	8.2 (1)
<i>Monotarsobius curtipes</i>	11.2 ± 2.9 (4)	<i>Lagria hirta larv.</i>	9.2 (1)
<i>Lithobius forficatus</i>	15.2 (1)	<i>Tortrix viridana larv.</i>	7.1 ± 0.9 (2)
<i>Opiliones</i>	11.8 ± 0.7 (2)	<i>Formica polyctena</i>	11.7 ± 1.2 (3)
<i>Carabus exelens</i>	17.3 (1)	<i>Tipula scripta larv.</i>	7.6 ± 1.2 (3)

microorganisms are the most important reserves of all three elements (nitrogen, potassium, phosphorus).

Maximal supplies of nitrogen in soil animals are concentrated in earthworm populations and the ratio of nitrogen amount in earthworms and microorganisms is almost the same as that of phosphorus. Nevertheless, nitrogen is more available for saprophages populations than phosphorus, so large supplies of nitrogen are in soil and litter.

Note, however, that a part of nitrogen bound in soil and litter exists in unavailable forms for animals for example, nitrogen of humic acids or mineral nitrogen and

hence, only microorganisms, which contain up to 80% proteins in their bodies, can supply animals with available forms of nitrogen.

This fact underlines only the significance of the microbial biomass as the source of nitrogen for saprophilous organisms.

Nitrogen is even more important as limiting factor for phytophages, so the ratio of its content in leafgrazing larvae and leaves is noticeably higher than that for phosphorus.

Table 2. Nitrogen content in soil and plant remains in percent of dry mass

Component	N [%]	Component	N [%]
Soil*	0.54	Bird -cherry leaf litter	3.30
Fresh oak leaf litter	1.50	Pear leaf litter	1.48
Oak leaves remaining on trees for the whole winter	1.38	Blackthorn leaf litter	2.15
Oak leaf litter	1.78	Aspen leaf litter	2.00
Ash leaf litter	0.90	Steppe litter	1.35
Dead grass roots	0.80	Dead steppe grass standing stems	0.60

\* after Orlov (1974)

Animal populations with different feeding types are said to be limited by the turnover of various chemical elements.

Judging from the distribution of elements and the total organic matter the best part of which is carbon, it can be said that carbon is not the limiting factor for animal population in spite of fact that it is the main element of living matter.

In some conditions nitrogen, phosphorus and potassium may determine the biomass and productivity of animal populations, not carbon or other chemical elements as our recent works have shown (Krivolutzky, Pokarzhevsky, 1977; Pokarzhevskij, Zhulidov, 1980; Pokarzhevskij, Krivolutzkij, 1981; Pokarzhevskij, Gordienko, 1983). It is of interest, that Satchell (1980) has found out that just the nitrogen deficit determined the impossibility to occupy some habitats by earthworms.

The distribution of an element in the biomass of various animal groups and their food cannot show real role of animals in element migration. Therefore it is necessary to count the value of the element concerned through animal populations.

During the growing period, soil saprophages in the forest-steppe can consumed 127 g/m<sup>2</sup> of plant remains which contain near 2.26 g/m<sup>2</sup> of nitrogen.

Nitrogen content of saprophages at their maximal biomass is 1.47 g/m<sup>2</sup> or only 1.5 times less than in food used. Even if we realize that saprophages have consumed with plant remains 1027 g/m<sup>2</sup> of soil which contains 5.55 g/m<sup>2</sup> of nitrogen, the value of flow (7.81 g/m<sup>2</sup>) is only five-times more than the nitrogen mass in the maximal

animal biomass and only 10 times than in mean biomass weight. Hence, as in the case with phosphorus biogenic migration (Pokarzhevskij, Gordienko, 1984), the additive source of chemical elements for animals is in microbial biomass. Consuming microbial cells, primarily with the soil, soil saprophages receive nitrogen required for surviving of their population.

It is also of importance, that the productivity of microbial populations is considerably higher than their mean biomass weight (Aristovskaja, 1980) and

Table 3. The distribution of nitrogen, potassium and phosphorus in some compartments of the forest-steppe oak forest ecosystem in kg/ha (after Pokarzhevskij, Krivolutzkij, 1981; Pokarzhevskij, Gordienko, 1984)

Compartment	Dry weight	Total organic matter	N	K*	P*
Soil (0—5 cm layer)	455 000	54 600	2 475	110	19.8
Trees and bushes leaves	4 300	4 085	86.0	29.0	10.0
Grass: green mass	2 700	2 325	43.2	19.1	6.4
roots	1630	1 415	16.3	9.9	4.6
Litter	14 000	2 100	249.2	87.0	14.0
Microorganisms	3 870	3 640	387.0	44.5	38.7
Nematodes	6.0	5.8	0.318	0.048	0.030
Enchytraeids	3.4	3.3	0.180	0.028	0.034
Earthworms	120.0	109.0	14.040	0.96	1.10
Molluscs	4.4	3.95	0.211	0.021	0.088
Wood lice	3.5	2.56	0.378	0.018	0.014
Diplopods	3.0	1.62	0.261	0.020	0.012
Chilopods	1.0	0.93	0.133	0.01	0.005
Spiders	0.2	0.19	0.018	0.002	0.0005
Insects					
in standing grass	0.1	0.09	0.011	0.003	0.0007
in litter and soil	6.0	5.58	0.618	0.072	0.042
leafgrazing larvae	20.0	18.96	1.42	0.26	0.058
Vertebrates	3.8	3.40	0.380	0.057	0.076

\* mass of available forms

therefore the consumption of microorganisms by soil animals does not practically affect the biomass of the microflora.

Total nitrogen mass flowing through soil saprophage populations, through plant remains and soil is near 62% of its mass in annual leaf litter. This is 15-times more than the relative value of phosphorus and potassium flow through their populations but is less than the relative value of the flows of calcium, magnesium and other elements studied.

It depends on the fact that three elements (nitrogen, phosphorus and potassium) in soil animals are received mainly from microbial populations but not only from plants, plant remains or soil humus.

Having defined the pool of the most important chemical elements, at least for animals, we find out that microorganisms are the main component of the soil subecosystem, influencing the productivity of animal populations, animal community structure in soil and hence the structure of the whole ecosystem.

Translated by A. D. Pokarževskij

#### References

- Aristovskaja, T. V., 1980: Microbiology of soil-forming processes (in Russian), Leningrad, Nauka, p. 186.
- Krivolutskij, D. A., Pokarževskij, A. D., 1977: The role of soil animals in nutrient cycling in forest and steppe. *Ecol. Bull.*, 25 p. 253—260.
- McBrayer, J. F., 1977: Contributions of cryptozoa to forest nutrient cycles. In: The role of arthropods in forest ecosystems. New York e.a., p. 70—77.
- Orlov, D. A., 1974: Gummy Acids (in Russian). Moscow, Vysshaja shkola, p. 331.
- Perkins D. F., 1978: The distribution and transfer of energy and nutrients in the *Agrostis — Festuca* grassland ecosystem. In: Production ecology of British moors and mountane grasslands. Berlin e.a., p. 375—395.
- Pleshkov, B. P., 1976: Practical works in plant biochemistry (in Russian). Moscow, Kolos, p. 251.
- Pokarževskij, A. D., Gordienko S. A., 1983: Soil animals in biogenic migration of phosphorus in forest-steppe ecosystems (in Russian). *Sov. J. of Ecol.*, 3 (in press).
- Pokarževskij, A. D., Krivolutskij, D. A., 1981: Turnover of elements and animal community structure in forest-steppe (in Russian). *Sov. J. of Ecol.*, 4, p. 67—72.
- Satchell, J. E., 1963: Nitrogen turnover by a woodland population of *Lumbricus terrestris*. In: Soil Organisms, Amsterdam, p. 60—65.
- Satchell, J. E., 1980: Potential of the Silpho Moor Experimental birch plots as a habitat for *Lumbricus terrestris*. *Soil Biol. Biochem.*, 12, p. 317—323.

Received 5. 8. 1983

Gordienko S. A., Pokarževskij A. D., Krivolutskij D. P., Severtzov A. N.: **Půdní živočichové a migrace dusíku v ekosystému.**

Migrace dusíku v ekosystému a úloha živočichů v tomto procesu byla studována v Aljechinově centrální černozemní biosferní rezervaci v Kursku. Dusík je nejdůležitější složkou živých organismů a je nedílnou součástí proteinů, nukleinových kyselin a aminokyselin. Hraje rozhodující úlohu v základních fyziologických a biochemických funkcích živé hmoty. Ve většině prostudovaných půdních druhů živočichů bylo zjištěno v sušině méně než 10 % dusíku. Prakticky ve všech půdních živočiších dochází ke koncentrování obsahu dusíku. Po stanovení procentuálního zastoupení nejdůležitějších chemických prvků u půdních živočichů i mikroorganismů se ukázalo, že mikroorganismy jsou hlavní složkou v půdním subekosystému, ovlivňující produktivitu populací živočichů, strukturu společenství živočichů v půdě a tím i strukturu celého ekosystému.